

Ultra-high Resolution Spectroscopic Remote Sensing: a Microscope on Planetary Atmospheres

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Remote sensing of planetary atmospheres is not complete without studies of all levels of the atmosphere, including the dense cloudy and haze filled troposphere, relatively clear and important stratosphere and the upper atmosphere, which are the first levels to experience the effects of solar radiation. High-resolution spectroscopy can provide valuable information on these regions of the atmosphere. Ultra-high spectral resolution studies can directly measure atmospheric winds, composition, temperature and non-thermal phenomena, which describe the physics and chemistry of the atmosphere. Spectroscopy in the middle to long infrared wavelengths can also probe levels where dust or haze limit measurements at shorter wavelength or can provide ambiguous results on atmospheric species abundances or winds. A spectroscopic technique in the middle infrared wavelengths analogous to a radio receiver, infrared heterodyne spectroscopy [1], will be describe and used to illustrate the detailed study of atmospheric phenomena not readily possible with other methods. The heterodyne spectral resolution with resolving power greater than 1,000,000 measures the true line shapes of emission and absorption lines in planetary atmospheres. The information on the region of line formation is contained in the line shapes. The absolute frequency of the lines can be measured to 1 part in 100,000,000 and can be used to accurately measure the Doppler frequency shift of the lines, directly measuring the line-of-sight velocity of the gas to ~1m/s precision (winds). The technical and analytical methods developed and used to measure and analyze infrared heterodyne measurements will be described. Examples of studies on Titan, Venus, Mars, Earth, and Jupiter will be presented. These include atmospheric dynamics on slowly rotating bodies (Titan [2] and Venus [3]) and temperature, composition and chemistry on Mars [4], Venus and Earth. The discovery and studies of unique atmospheric phenomena will also be described, such as non-thermal and lasing phenomena on Mars and Venus, mid-infrared aurora on Jupiter [5], and results of small body impacts on Jupiter [6]. The heterodyne technique can also be applied for detailed study of the Earth's stratosphere and mesosphere by measuring trace constituent abundances and temporal and spatial variability as well as winds, which provide information of transport. All ground-based measurements will be described as complementary and supporting studies for on-going and future space missions [7] (Mars Express, Venus Express, Cassini Huygens, JUNO, ExoMars Trace Gas Orbiter, and the Europa Jupiter System Mission, an Earth Science Venture Class missions). Proposed instrument and technology development for a space flight infrared heterodyne spectrometer will be described.

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References

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